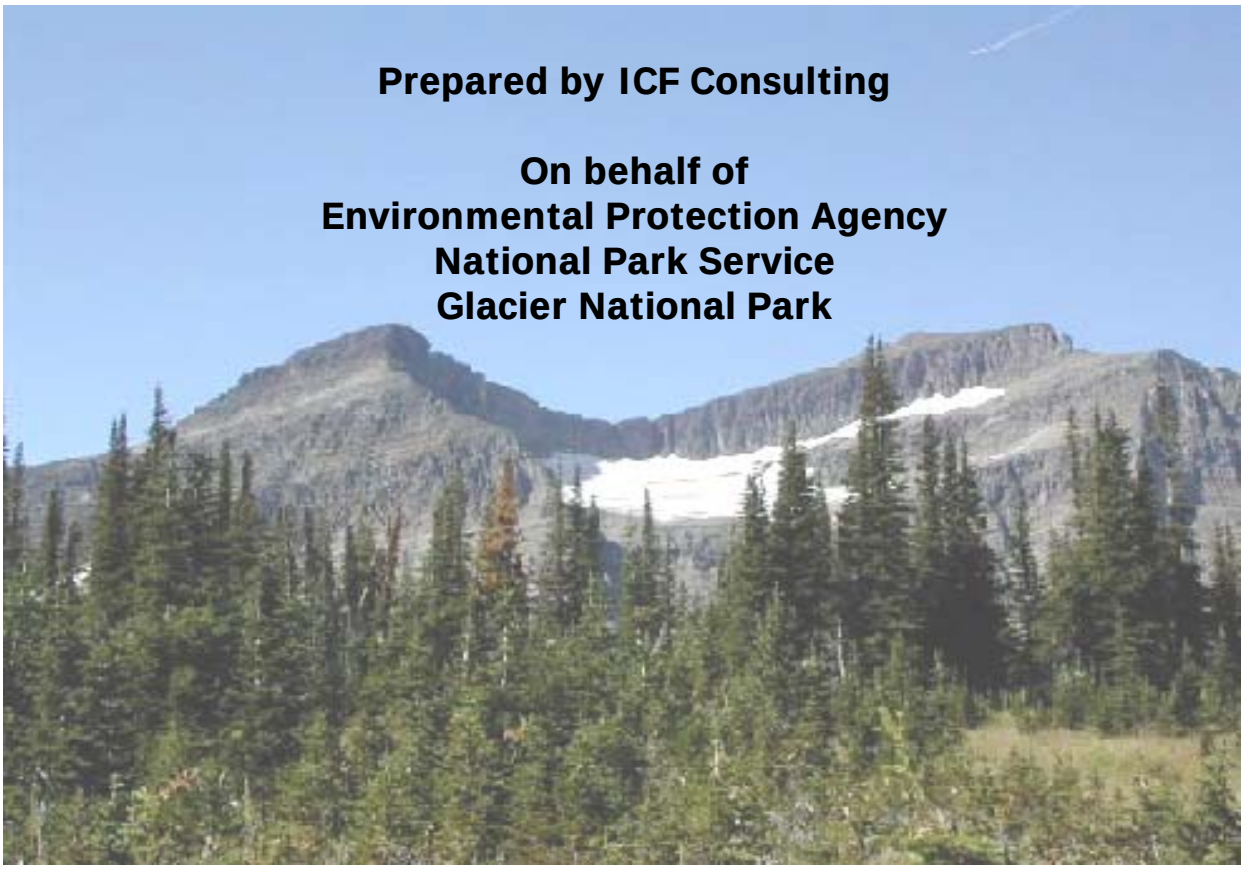
GREENHOUSE GAS EMISSIONS INVENTORY

GLACIER NATIONAL PARK

April 19, 2004



ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

This report provides an inventory of greenhouse gas (GHG) emissions associated with activities at Glacier National Park. The Glacier inventory is the first GHG emission inventory of a western park and the second GHG inventory ever conducted for a national park.[1] These inventories have been developed in conjunction with a pilot project initiated by the National Park Service (NPS), with assistance from the Environmental Protection Agency (EPA). The pilot project was designed to establish a Climate Friendly Parks Program within the NPS Green Parks Partnership Program. The Climate Friendly Parks Program aims to reduce park-related GHG emissions and to inform the public about the climate-friendly actions each park is taking and the reasoning behind the actions.

The purpose of this inventory is to provide the foundation for discussions of GHG emissions at Glacier and to assist park officials in identifying ways to reduce these emissions. In addition, the inventory will provide Glacier with a baseline against which future actions to reduce emissions may be compared.

Air emission inventories, of which GHG inventories are a subset, are often—but not necessarily—prepared for regulatory reasons. Emission regulations or statutes require air emission inventories to determine the amount of pollutants released to the atmosphere. For example, the Clean Air Act, as amended in 1990, sets forth requirements for specific inventories, such as base year inventories for State Implementation Plans. In addition, the development of regulations often necessitates a nationwide inventory of emissions from a particular industry or type of emission source. On a smaller scale, facility-specific inventories are used as the basis for construction and operating permits, determining compliance with existing permit conditions or emission regulations, conducting environmental impact assessments for proposed new emission sources, and for input to human health risk assessment studies.

Although no existing federal regulations limit GHG emissions, concern over the prospect of global warming[2] has prompted the development of corporate, state, regional, national, and global inventories. This national park inventory includes estimates of GHG emissions from activities attributable to park operations (e.g., stationary combustion, mobile combustion). Once emissions from these sources are measured, the park may consider options to reduce emissions. In the interest of considering a full range of options for reducing emissions, the GHG inventory for Glacier also includes "indirect emissions," or emissions from sources that are not directly within the park's control, but which the park has some influence over (e.g., purchased electricity, visitor vehicle emissions, concessionaire operations, waste management). Consideration of these indirect emissions will both expand the park's portfolio of possible emission reduction actions and enable the park to work with its electricity providers, waste haulers, concessionaires, and visitors to reduce park-related emissions occurring outside park boundaries.

Glacier National Park was founded in 1910 as the country's 10th national park. The park is located in northwest Montana on the border between the United States and Canada. On the Canadian side lies Waterton Lakes National Park in Alberta. In 1932, the United States and Canadian governments voted to designate Waterton-Glacier the world's first International Peace Park as a symbol of the longtime peace and friendship between the two countries (NPS 2004). This inventory presents GHG emissions associated with

[1] A few western parks have included CO_2 in their air emissions analyses; however the only other inventory of GHG emissions (i.e., including CO_2 and non-CO_2 GHGs) at a national park was conducted for Gateway National Recreation Area in 2003. The report is entitled *Criteria Air Pollutant and Greenhouse Gas Emission Inventory: Gateway National Recreation Area*, prepared by ICF for EPA, NPS, and Gateway National Recreation Area, May 2003.

[2] For an explanation of global warming, visit EPA's Global Warming Site: <http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html>.

activities within the United States boundaries of the park. A separate effort to quantify GHG emissions at Waterton is also underway as part of the Environmental Management System of Parks Canada, but these data are not included here.

Glacier National Park comprises over one million acres of forested, mountainous terrain, grasslands, meadows, and mountain lakes. It has been estimated that around 150 glaciers existed inside park boundaries around 1860. Since that time, due to a warming climate, these have been reduced to 37 named glaciers. The park is keenly interested in the potential impacts that climate change is having, and will continue to have, on the natural features of the park.

The sources included in this inventory were chosen based on (1) whether the activity occurs at the park; (2) whether opportunities exist for reducing emissions from the activity; (3) whether emissions from each source were significant enough to warrant substantial data collection and emission estimation efforts; and (4) whether data were available for collection. The GHG sources reported in this inventory include:

- Carbon dioxide, methane, and nitrous oxide from stationary combustion
  - direct combustion
  - purchased electricity (indirect)
- Carbon dioxide, methane, and nitrous oxide from mobile combustion
  - highway vehicles
  - nonroad vehicles
- Methane from waste disposal

In addition to estimating emissions by source, emissions from each source were broken down into park-owned and leased, concessionaire-owned, and visitor activities. The remainder of the executive summary provides an overview of emissions for Glacier as a whole, provides some analysis of the key sources of emissions, and compares Glacier's emissions with those at Gateway National Recreation Area.

ES.1 GLACIER NATIONAL PARK GREENHOUSE GAS EMISSIONS

Naturally occurring GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone (O_3). Human activities (e.g., fuel combustion in stationary and mobile sources, and waste disposal) lead to increased concentrations of these gases in the atmosphere. In addition, there are other more powerful GHGs—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—called high-global warming potential (high-GWP) gases that are created by various industrial processes. Global warming potentials are assigned to various pollutants to weight their ability to trap heat in the atmosphere. This ability is measured relative to the most commonly occurring GHG, CO_2, which has a GWP of 1. GHGs inventoried for Glacier included CO_2, CH_4, and N_2O. In order to compare emissions of these gases with different heat trapping abilities, the GWPs for each gas were used to express emissions for Glacier in metric tons of carbon equivalent (MTCE).[3]

CO_2 emissions from fuel combustion in vehicles, by far, accounted for the greatest portion of GHG emissions (82 percent), followed by CO_2 emissions from purchased electricity (7 percent), CO_2 emissions from fuel combustion in stationary sources (5 percent), and CH_4 emissions from landfilling (4 percent).

Table ES-1 presents a summary of Glacier's GHG emissions in MTCE by gas.

[3] Carbon comprises 12/44 of the mass of CO_2. To convert from CO_2 equivalent to C equivalent, emissions were multiplied by 12/44.

Table ES-1: Glacier Summary of GHG Emissions

Source / Operation	Emissions (MTCE)			
	CO_2	CH_4	N_2O	Total
Stationary Combustion	**846.0**	**8.1**	**1.7**	**855.9**
Direct Combustion	350.0	8.1	1.7	359.9
Indirect – Purchased Electricity	496.0	NE	NE	496.0
Mobile Combustion	**5,953.8**	**13.4**	**169.1**	**6,136.3**
Highway Vehicles	5,946.2	13.3	168.7	6,128.2
Nonroad Vehicles/Equipment	7.6	0.1	0.4	8.1
Waste Disposal	**NA**	**306.4**	**NA**	**306.4**
TOTAL	**6,799.9**	**327.8**	**170.8**	**7,298.5**

Note: Totals may not sum due to independent rounding.
NE = Not Estimated. NA = Not Applicable.

As shown in Figure ES-1, CO_2 accounted for the vast majority of GHG emissions from Glacier, as it does in virtually all state and national GHG emission inventories. Figure ES-2 presents the breakdown of emissions from each of the key categories listed in Table ES-2: stationary combustion, purchased electricity, highway vehicles, nonroad vehicles/equipment, and landfilled waste.

Figure ES-1: Glacier GHG Emissions by Gas

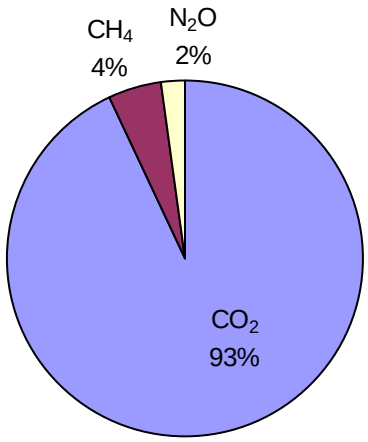
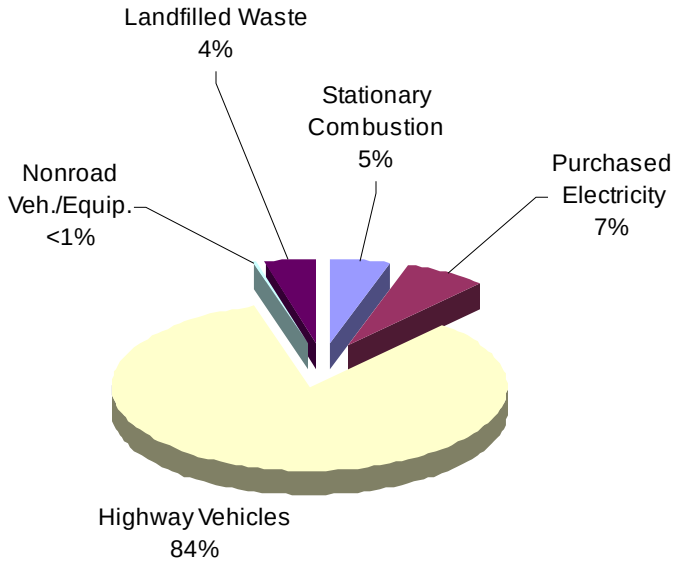


Figure ES-2: Glacier GHG Emissions by Source



The body of the report separates Glacier's overall emissions into three categories: park-owned and leased operations, concessionaire operations, and visitor activities. Note that the National Park Service and its concessionaires are responsible for paying for electricity used by visitors in park buildings and concessionaire facilities. Similarly, the National Park Service and park concessionaires are responsible for managing visitor-generated wastes. For these reasons, visitor emissions from stationary combustion and waste disposal were unable to be quantified separately. Instead, electricity consumption and waste generation attributable to Glacier's visitors are reflected in the estimates for the park or the concessionaires that provide those services.

ES.2 KEY SOURCES

Transportation-related activities comprise the majority of emissions at Glacier and there is a wide disparity in emissions associated with park operations, concessionaire operations, and visitor activities. Figure ES-3 below provides an illustration of transportation-related emissions from these three categories. As the graph indicates, visitor emissions dominated the emission profile, and in all cases, CO_2 accounted for the majority of emissions.

Figure ES-3: Park, Concessionaire, and Visitor-Related Transportation Emissions

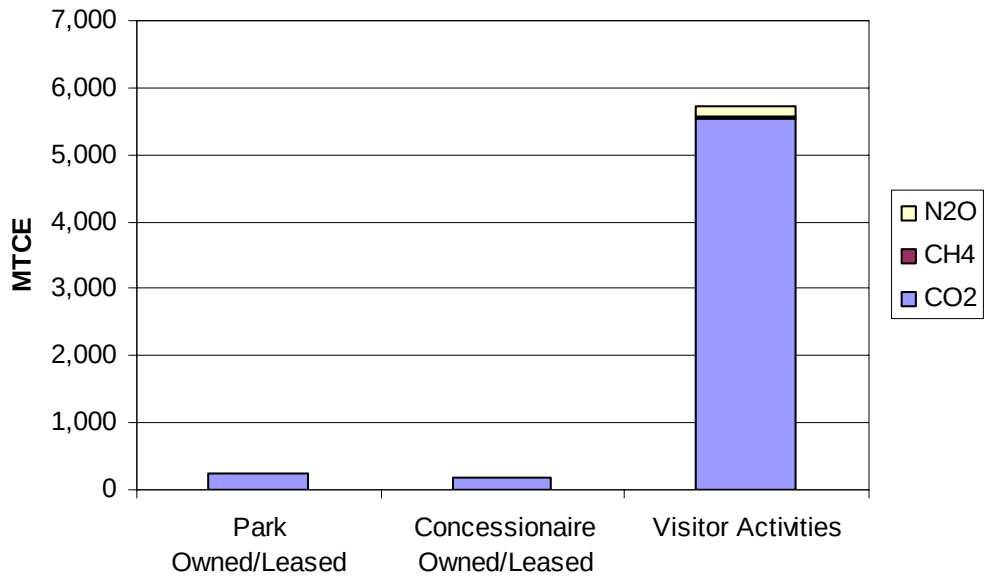


Table ES-2 presents a detailed accounting of transportation emissions at Glacier. Emissions are provided by subcategory (highway vehicles and nonroad vehicles) and by ownership class (park, concessionaire, visitor). Nonroad emissions are further disaggregated into two categories nonroad vehicles/equipment and boats. As the columns at the far right demonstrate, highway vehicles account for nearly all of the transportation-related emission at the park. Visitor highway vehicle use accounts for 93 percent of transportation emissions, followed by park highway emissions of 4 percent and concessionaire highway emissions of 3 percent. Within the nonroad category, park operations accounted for 5 percent of emissions, while concessionaire boat-related emissions accounted for 95 percent of nonroad emissions.

Table ES-2: Highway Emissions

Source Category	Emissions (MTCE)				% of Transp Total	% of Sub Category Total
	CO_2	CH_4	N_2O	Total		
Highway Vehicles	**5,946.2**	**13.3**	**168.7**	**6,128.2**	**100%**	**100%**
Park-Owned and Leased Operations	236.8	0.5	6.0	243.3	4%	4%
Concessionaire-Owned Operations	163.9	0.4	3.3	167.6	3%	3%
Visitor Activities	5,545.6	12.4	159.4	5,717.3	93%	93%
Nonroad Vehicles	**7.6**	**0.1**	**0.4**	**8.1**	**<1%**	**100%**
Equipment/Nonroad Vehicles						
Park-Owned and Leased Operations	IE	0.1	0.3	0.4	<1%	5%
Concessionaire-Owned Operations	NAV	NAV	NAV	NAV	<1%	<1%
Visitor Activities	NAV	NAV	NAV	NAV	<1%	<1%
Boats						
Park-Owned and Leased Operations	IE	+	+	+	<1%	<1%
Concessionaire-Owned Operations	7.6	+	0.1	7.7	<1%	95%
Visitor Activities	NAV	NAV	NAV	NAV	<1%	<1%
TOTAL EMISSIONS	**5,953.8**	**13.4**	**169.1**	**6,136.3**	**100%**	**NA**

Note: Totals may not sum due to independent rounding.
NA = Not Applicable. IE = Included Elsewhere. NAV = Not Available. + Does not exceed 0.05 MTCE.

ES.3 EMISSIONS IN CONTEXT

There are not many points of comparison for Glacier's inventory, given that this is only the second GHG inventory ever conducted for a national park. The only other park inventory completed to date that includes CO_2, CH_4, and N_2O is for Gateway National Recreation Area. Gateway is an urban park, located in the New York metropolitan area and in northern New Jersey. The park was established in 1972 as America's first urban national park. The park extends across 26,000 acres of land and water, including former military fortifications, one of the largest bird sanctuaries in the northeastern United States, and several miles of beaches. Gateway receives more than 10 million visitors each year. In comparison, Glacier was founded in 1910, is located in northwestern Montana, spans more than one million acres including more than 500,000 acres of forest, and is visited by approximately 1.9 million people each year.

When the emissions for these two parks were compared, it was interesting to note how similar the emission profiles were, given the differences in the environment, scale, location, and visitorship of these two parks. Table ES-3 provides a comparison of emissions in MTCE for each of the parks. Note that the Gateway total has been adjusted downward to reflect the sources that were not relevant and/or included in the Glacier inventory (e.g., emissions associated with motor vehicle air conditioning). As the table indicates, emissions from the two parks are within the same order of magnitude. In addition, CO_2 emissions from fossil fuel combustion accounts for the majority of emissions for both parks (93 percent of emissions at Glacier versus 97 percent of emissions at Gateway).

The most notable differences between Glacier and Gateway's emissions results lie in their purchased electricity and landfilled waste GHGs. Gateway reported far higher emissions associated with purchased electricity—nearly four times larger than Glacier. Although Gateway did purchase about twice as much electricity than Glacier park and its concessionaires, Gateway's higher emission results from this source can also be attributed to a more fossil driven fuel mix in Gateway's electricity supply. Glacier purchases electricity from a power control area that uses a fuel mix comprised of 53 percent renewable fuels as compared to only 2 percent renewable content, on average,[4] of the electricity supplied to Gateway (EPA 2003). Waste-related emissions were significantly higher at Glacier than at Gateway primarily due to the absence of landfill gas recovery projects at the landfills where Glacier's waste is disposed. Gateway's waste is disposed in landfills with flaring or landfill-gas-to-energy systems in place; therefore, CH_4 generated during decomposition is largely destroyed.

Perhaps the most interesting comparison of Glacier and Gateway's emission estimates is the comparison of transportation-related emissions from visitors. In both parks, visitor vehicle traffic was the single largest source of emissions. In fact, visitor vehicle emissions from Gateway and Glacier each accounted for 95 and 93 percent of their respective park's total mobile emissions. The total number of miles traveled in each park "drive" these emissions. While Glacier welcomed only 1.9 million visitors in 2002 as compared to the approximate 10 million that enter Gateway each year, Glacier spans over one million acres versus the 26,000 acres of Gateway. Thus, visitors to Glacier drive a greater number of miles within the park's boundaries. The Going-to-the-Sun Road in Glacier alone covers 55 miles. The combination of high mileage and a low number of visitor vehicles in the case of Glacier and low mileage and a high number of visitor vehicles at Gateway led to comparable emission results from visitor vehicles in the two parks. The greater driving per visitor in Glacier also helps explain Glacier's higher emissions per visitor ratio; dividing the parks'

[4] Note that Gateway's electricity comes from two eGRID subregions, NPCC NYC/Westchester and MAAC All, because the park covers two states (i.e., New York and New Jersey).

total GHG emissions by their 2002 visitation shows that Glacier emits nearly 5 times more GHGs per visitor than does Gateway (8.4 pounds per visitor in Glacier versus 1.7 pounds per visitor in Gateway).

Table ES-3: Emissions Comparison: Glacier vs. Gateway

Source Category	Total Emissions (MTCE)	
	Glacier	Gateway
CO_2 from Fossil Fuel Combustion	**6,799.9**	**7,648.1**
Direct Combustion	6,303.9	5,702.4
Indirect - Purchased Electricity	496.0	1,945.7
CH_4 and N_2O from Stationary Combustion	**9.8**	**6.0**
CH_4 and N_2O from Mobile Combustion	**182.5**	**132.0**
Highway Vehicles	182.0	130.7
Nonroad Vehicles	0.5	1.3
Equipment/Nonroad Vehicles	*0.4*	*0.3*
Boats	*0.1*	*1.1*
Landfilled Waste	**306.4**	**64.6**
TOTAL	**7,298.5**	**7,850.7**

Note: Totals may not sum due to independent rounding.

ES.4 Possible Actions to Reduce Emissions

Glacier's emissions account for less than 1 percent of Montana's overall emissions; however, many opportunities to reduce the park's GHG emissions still exist at Glacier. The park and concessionaires can take a number of steps to reduce Glacier's CO_2, CH_4, and N_2O emissions and save money in the long run, beyond those initiatives that are already underway at the park (e.g., red bike program, natural gas usage). Throughout this report, actions to reduce GHGs from stationary, mobile, and waste activities are recommended and, where possible, the savings are described. Table ES-4 presents an overview of possible actions that Glacier can take to reduce emissions, increase awareness on climate change, and, in many cases, experience long-term cost savings.

Table ES-4: Possible Actions for Reducing GHG Emissions

Category/Action	Benefits
Facilities	
Switch a greater share of petroleum usage to natural gas	Reduction in CO_2, CH_4, and N_2O from use of a lower carbon intensive fuel
Reduce overall fuel use	Reduction in CO_2, CH_4, and N_2O from lowered energy use; Long-term cost savings
Install energy efficient lighting	
Install energy efficient appliances	
Improve building insulation (repair or replace windows)	
Install motion sensors	
Purchase green power (electricity generated using lower carbon fuels or renewable energy)	Reduction in CO_2, CH_4, and N_2O from lowered electricity use
Coordinate purchasing/institute materials exchange between East and West sides of park	

Category / Action	Benefits
Transportation	
Install visitor/hiker alternative fuel shuttle	Reduction in CO_2, CH_4, and N_2O from reduced visitor vehicle driving
Establish incentives for use of hybrid and alternative fuel vehicles in the park (e.g., increased access, entrance fee waiver)	
Install employee alternative fuel shuttle	Reduction in CO_2, CH_4, and N_2O; Cost savings to employees
Implement employee carpooling program within the park	
Purchase alternative fuel or hybrid vehicles to replace aging park-owned or leased highway vehicles and nonroad vehicles/equipment	Reduction in CO_2, CH_4, and N_2O
Reduce equipment use	
Waste	
Increase recycling program in park (expand to include other materials beyond cardboard, plastic, and paper)	Reduction in CH_4; Education for park and concessionaire employees and visitors "Upstream" energy GHG benefits as well
Compost yard trimmings and food scraps from park and concessionaire food services	
Reduce paper use in park (rely more on electronic transmission of information)	Reduction in CH_4
Reuse materials in park (wood waste, used brick, cardboard boxes)	Reduction in CH_4; Cost savings "Upstream" energy and carbon sequestration benefits as well
Purchase items in bulk to reduce the overall need for packaging materials	
Education / Outreach	
Educate park staff on climate change during orientation, workshops, or brown bags	Education to employees
Provide outreach materials to visitors on climate change (e.g., general or CFP information)	Education to visitors
Post climate change info on park web site	Education to visitors and virtual visitors
Update signage on Going-to-the-Sun Road to explain that glacial retreat in being enhanced by increased GHG emissions from human activities	Education to visitors

1 INTRODUCTION

1.1 BACKGROUND & PURPOSE

Since the late 1990s, the National Park Service (NPS) and Environmental Protection Agency (EPA) have undertaken efforts to help parks improve their management of natural resources, implement green practices, and become better stewards of the environment. Examples of these initiatives include the NPS Natural Resource Challenge, the NPS Environmental Leadership Program, and EPA's longstanding support to parks and outdoor enthusiasts on climate change. In 2002, the NPS Green Partners Program evolved out of the NPS Environmental Leadership Program. The main objective of the Green Partners Program was to identify key partners that could assist parks in accelerating the implementation of green strategies and practices. As part of this program, NPS partnered with the EPA to launch the Climate Friendly Parks (CFP) pilot project in 2002. The CFP Program has four key objectives:

- Supporting the President's Climate Change Initiative
- Supporting a Federal model of environmental excellence
- Achieving greenhouse gas reductions and energy savings
- Protecting natural resources

These objectives are achieved as individual parks partner with EPA and NPS national programs to become more climate-friendly. The CFP Program assists parks in educating staff about the issue of climate change, estimating baseline emissions of greenhouse gases (GHGs), identifying opportunities to reduce park emissions, and developing materials and methods to inform the public about the climate-friendly actions underway in the park.

One of the most important steps for parks interested in becoming more climate-friendly is conducting an inventory of GHG emissions. This step is critical because until park staff and concessionaires know which activities are contributing to emissions and the relative magnitude of emissions from each source, they will not know where to focus their emission reduction efforts. In addition, the inventory will provide Glacier staff and concessionaries with a baseline against which future actions to reduce emissions may be compared.

This report presents GHG emissions associated with activities in Glacier National Park. Glacier National Park follows Gateway National Recreation Area as the second U.S. park to participate in the CFP Program and to develop an inventory of GHG emissions. By participating in the program, Glacier helps lead the way toward implementation of more climate-friendly practices in parks nationwide.

1.2 RATIONALE FOR INVENTORYING GHG EMISSIONS

A criteria air pollutant emission inventory was completed for Glacier National Park in 2002 (NPS 2002). These pollutants,[5] which are considered harmful to public health and the environment but do not affect climate change, are regulated under the Clean Air Act. Emission inventories originally focused on criteria air pollutants to ensure compliance with regulations and to help mitigate these emissions; however, international efforts to address global warming have prompted the development of national, state, and local GHG inventories.

[5] Criteria air pollutants include sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), lead (Pb), ground-level ozone (O_3), and particulate matter (PM).

Actions to address increasing GHG emissions began in the early 1990s. In 1992, the United States joined with 154 other nations at the United Nations Conference on Environment and Development (also known as the Earth Summit) in signing the Framework Convention on Climate Change (FCCC). Later that year, the United States became the first industrialized nation to ratify the FCCC Treaty, which came into force on March 21, 1994. The FCCC commits signatories to stabilizing anthropogenic GHG emissions to "levels that would prevent dangerous anthropogenic interference with the climate system." To facilitate these goals, Article 4-1 of the FCCC treaty requires that all parties to the FCCC develop, periodically update, and make available to the Conference of the Parties, national inventories of anthropogenic emissions of all GHGs not controlled by the Montreal Protocol.

The U.S. government has published annual GHG inventories—most recently the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001* (EPA 2003b)—to fulfill its obligation under the FCCC. This series of national inventories tracks the emissions of each GHG, by source, and provides a benchmark for efforts to reduce emissions. In addition, EPA has set voluntary goals for GHG emission reduction through its "Climate Leaders" initiative, set forth in February 2002. Under this program, EPA encourages industries to measure GHG emissions and take steps to reduce GHG intensity by 18 percent over the next ten years. To the extent that Glacier can inventory and then track changes in GHG emissions over time, the park may be able to reduce emissions and set an example for park visitors.

In December 2003, Glacier National Park, NPS, and EPA held a CFP workshop in Whitefish, Montana. Park and concessionaire employees, with guidance from EPA and NPS staff, identified a number of climate-friendly action items that they would like to undertake at Glacier as both short and long-term goals. Some of these are listed in Box 1.1. Implementing such programs would lead to significant reductions in GHG emissions, which could be measured using this inventory as a baseline.

Box 1.1: Examples of Short Term and Long Term Action Items Identified at CFP Workshop

Transportation

Short term:

- Adopt "red bike" program for short trips between NPS buildings
- Initiate carpooling program to match and coordinate driving in the park

Long term:

- Develop shuttle service alternative for visitors

Facilities Management

Short term:

- Convert diesel fleet to 100 percent biodiesel
- Reduce vehicle idling time

Long term:

- Use "green" design for future West side visitor's center

Resource Management

Short term:

- Create "green filter" criteria for product purchase, construction, design, deconstruction
- Define GNP Best Management Practices for park projects

Long term:

- Address managing resources in a changing environment in the new Resources Management Plan

Visitor Protection/Fire Management

Short term:

- Incorporate climate change information into seasonal staff orientation
- Educate visitors about climate change impacts

Long term:

- Eco-friendly patrol units with non-motorized and alternative fuels vehicles

1.3 PARK DESCRIPTION

Glacier National Park was founded in 1910 as the country's 10th national park. The park is located in northwest Montana on the border between the United States and Canada (see map in Figure 1.1). On the Canadian side lies Waterton Lakes National Park in Alberta. In 1932, the United States and Canadian governments voted to designate Waterton-Glacier the world's first International Peace Park as a symbol of the longtime peace and friendship between the two countries (NPS

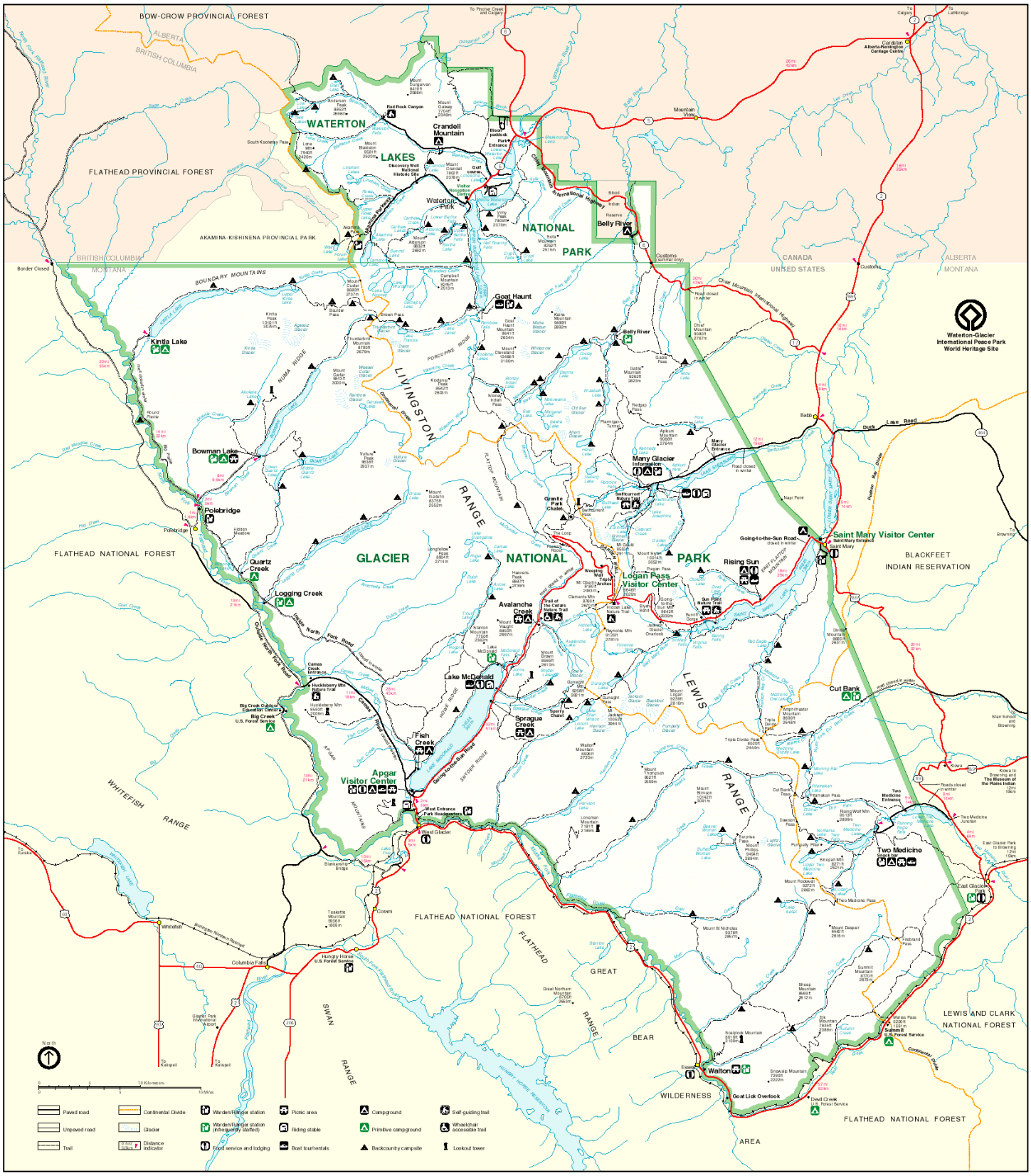
2004). This inventory presents GHG emissions associated with activities within the United States boundaries of the park. A separate effort to quantify GHG emissions at Waterton is also underway as part of the Environmental Management System of Parks Canada, but these data are not presented here.

Glacier is the fifth largest national park in the lower 48 states, encompassing over one million acres of a richly diverse ecosystem (Crown of the Continent Ecosystem) and heterogeneous landscape. Two major continental biomes and 5 major floristic provinces, ranging from mesic boreal forest and alpine tundra to semi-arid grassland are represented in the park. Forests comprise more than half of the park's area, 568 thousand acres, and account for 2.4 percent of the forested land in Montana.

Glaciers in the park began receding around 1860, at which time it is estimated that there were 150 glaciers within the park boundaries. Today, only 37 named glaciers remain and most of them are a mere fraction of their original size, a testament to the warming climate. Scientists report that glaciers within the park melted by 66 percent between 1850 and 1979, during which time global temperatures increased by 0.45ºC ± 0.15ºC (Hall and Fagre 2003).

In addition to park operations, concessionaires are in charge of numerous facilities and activities within the park from lodging to boat rental. In 2002, the park employed about 440 people, compared to about 1,850 employed by concessionaires (Summerfield 2003, Baker 2003, Meredith 2003). Glacier Park, Inc. is the largest concessionaire, operating seven lodges and the largest fleet of tour buses. In 2002, the park welcomed approximately 1.9 million visitors or an average of 5,237 visitors per day (Law 2003). The majority of these visitors came to Glacier during the peak season of May through October. Glacier offers a wide range of activities for visitors, including camping, hiking, boating, fishing, bicycling, horseback riding, cross-country skiing, snowshoeing, and sightseeing among some of the most beautiful landscapes in the country.

Figure 1.1: Map of Waterton-Glacier International Peace Park



1.4 INVENTORY METHODOLOGY

The methodology used to develop Glacier's GHG emission inventory involved the following steps:

1) Developed a list of data necessary to estimate GHG emissions at Glacier;
2) Provided a data request form to Glacier;
3) Visited Glacier in August 2003 to collect data from park and concessionaire personnel;
4) Reviewed data provided by the park and concessionaires;
5) Attempted to fill data gaps through conversations with park staff and independent research;
6) Estimated GHG emissions;
7) Presented emission results at CFP workshop in December 2003;
8) Refined estimates; and
9) Developed an inventory report.

Data were collected and reported separately by park-owned, park-leased (i.e., GSA leased vehicles), concessionaire, and visitor activities. Glacier National Park chose to inventory emissions for the year 2002. The approach used to measure GHGs from anthropogenic (human activities) at Glacier is consistent with the methods used at the state and national levels.

1.5 OVERVIEW OF GHG SOURCES & DISCUSSION OF SOURCES INCLUDED IN INVENTORY

Naturally occurring GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor, and ozone (O_3). Human activities (e.g., fuel combustion in stationary and mobile sources, agriculture, and waste generation) lead to increased concentrations of these gases in the atmosphere. In addition, there are other more powerful GHGs—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) (i.e., chemicals composed of carbon and fluorine), and sulfur hexafluoride (SF_6)—that are created by various industrial processes. The ability of a gas to trap heat in the atmosphere is measured by its Global Warming Potential (GWP). GWP is a weighting factor used to measure the ability of a gas to trap heat in the atmosphere. This ability is measured relative to the most commonly occurring GHG, CO_2, which has a GWP of 1. As a comparison, CH_4 has a GWP of 21. Therefore, one unit of CH_4 is as effective at trapping heat in the atmosphere as 21 units of CO_2. Table 1.1 presents a list of GHGs and their associated GWPs. The GHGs inventoried in this report include CO_2, CH_4, and N_2O.

Table 1.1: Global Warming Potentials

Gas	GWP[a]
Carbon dioxide (CO_2)	1
Methane (CH_4)[b]	21
Nitrous oxide (N_2O)	310
HFC-23	11,700
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

Source: IPCC 1996[6]
[a] 100-year time horizon
[b] The CH_4 GWP includes the direct and indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.

In accordance with the GHG emission sources and sinks reported by the Intergovernmental Panel on Climate Change (IPCC) in *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 1997), EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001* (2003b), and EPA's *Emission Inventory Improvement Program Guidelines, Vol. VIII Estimating Greenhouse Gas Emissions* (2003a), GHG emission sources and sinks include the following activities: energy, industrial processes, solvents and other product use, agriculture, land use change and forestry, and waste. The specific emission sources under these activities are included in Table 1.2.

The sources included in this inventory were based on (1) whether the activity occurs at the park; (2) whether opportunities exist for reducing emissions from the activity;[7] (3) whether emissions from each source were significant enough to warrant substantial data collection and emission estimation efforts; and (4) whether data were available for collection. With respect to the first criterion, coal mining, natural gas and oil systems, international bunker fuels, most of the industrial process source categories, rice cultivation, agricultural residue burning, and waste combustion were not applicable to Glacier. With respect to the second criterion, emissions of HFCs and PFCs from the consumption of substitutes for ozone depleting substances used in refrigeration and air conditioning were not estimated for Glacier because there are no alternatives to these substitutes currently available. On the third point, other sources, such as solvent use,

[6] The GWPs listed above are from IPCC's Second Assessment Report (SAR). These were updated by IPCC in the Third Assessment Report (TAR); however, the UNFCCC reporting guidelines for national inventories continue to require the use of the SAR GWPs so that current estimates of aggregated GHGs are consistent with estimates developed prior to the publication of the TAR. Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported using SAR GWP values.

[7] This criterion was established when the budget and scope of the inventory were assessed; based on the resources available and time constraints, only those sources with available mitigation options were included.

enteric fermentation and manure management (for horses and other animals in the park), fertilizer use, and wastewater treatment[8] were deemed too small to quantify. In regards to the fourth criterion, inclusion of all applicable and significant sources was limited by a shortened timeframe for gathering data combined with difficulties obtaining some of the necessary data from park and concessionaire personnel.

Table 1.2 presents the GHG emission sources, their relevance for Glacier, and whether or not they were estimated for Glacier. Although only a selection of the sources listed below was both relevant and estimated for Glacier, these in fact represent most of the key sources of GHGs. The table intends to provide a comprehensive list of the full spectrum of sources that emit GHGs beyond just the park level.

Table 1.2: GHG Emission Sources

Pollutant/Source Category	Relevant for Glacier	Estimated for Glacier	Reason Relevant Sources Missing from Inventory
GHG Source			
Energy			
CO_2, CH_4, and N_2O from Stationary Combustion	Y	Y	
CO_2, CH_4, and N_2O from Mobile Combustion	Y	Y	
Highway Vehicles	Y	Y	
Nonroad Vehicles	Y	Y[a]	*Concessionaires*: Data not provided, or in the case of Glacier Park Inc., estimated fuel consumed by highway vehicles exceeded reported fuel consumption. *Visitors*: Necessary data on boat use are not collected at the park. Aviation emissions were not quantified due to the difficulty in obtaining the necessary data and quantifying emissions given resources available.
CH_4 from Coal Mining and Natural Gas and Oil Systems	N	N	
CO_2 from Natural Gas Flaring	N	N	
CO_2, CH_4, and N_2O from International Bunker Fuels	N	N	
Industrial Processes			
CO_2 from the Production of Cement, Lime, Iron and Steel, and Titanium Dioxide; Limestone and Dolomite Use; Soda Ash Manufacture & Consumption; Ammonia Production & Urea Application; Ferroalloys; and CO_2 Consumption	N	N	
CH_4 from Silicon Carbide and Petrochemical Production	N	N	
N_2O from Nitric and Adipic Acid Production	N	N	
CO_2 and PFCs from Aluminum Production	N	N	

[8] Wastewater treatment can result in emissions of N_2O and CH_4. In Glacier's case, CH_4 was not emitted because the wastewater is aerobically treated. There are emissions of N_2O from Glacier's wastewater treatment plant, but they are likely to be extremely small. In EPA's U.S. Inventory, N_2O emissions accounted for only about 0.2 percent of U.S. emissions in 2002. In addition, the method for estimating emissions from wastewater treatment is very uncertain. For all of these reasons, the planning team agreed to omit this source from the inventory.

Pollutant/Source Category	Relevant for Glacier	Estimated for Glacier	Reason Relevant Sources Missing from Inventory
HFCs and PFCs from Consumption of Substitutes for Ozone-Depleting Substances (Refrigeration & Air Conditioning)	Y	N	Opportunities do not exist to reduce emissions from this activity (e.g., no alternatives to these substitutes currently available).
PFC, HFC, and SF_6 from Semiconductor Manufacture and HFC-23 from HCFC-22 Production	N	N	
SF_6 from Electric Power Transmission & Distribution and Magnesium Production & Processing	N	N	
Solvent Use	Y	N	Deemed too small to quantify given resources available.
Agriculture			
CH_4 from Enteric Fermentation	Y	N	Deemed too small to quantify given resources available.
CH_4 and N_2O from Manure Management	Y	N	Deemed too small to quantify given resources available.
CH_4 from Rice Cultivation	N	N	
N_2O from Agricultural Soil Management (Fertilizer Use)	Y	N	Deemed too small to quantify given resources available.
CH_4 and N_2O from Agricultural Residue Burning	N	N	
Land-use Change and Forestry			
Changes in Forest Carbon Stocks (including fires)	Y	Y[a]	Necessary data on prescribed burning and 2002 wildfires were not available from the park to estimate flux.
Changes in Carbon Stocks in Urban Trees, Agricultural Soil Carbon Stocks, and Carbon Stocks from Landfilled Yard Trimmings	N	N	
Waste			
CH_4 from Landfills	Y	Y	
CO_2 and N_2O Waste Combustion[b]	N	N	
CH_4 from Wastewater Treatment	N	N	Wastewater is aerobically treated, yielding no CH_4 emissions.
N_2O from Human Sewage	Y	N	Deemed too small to quantify given resources available; also, no readily available mitigation options

Note: Y = Yes; N = No.
[a] Estimated where data allowed.
[b] Sometimes included under the Energy sector.

1.6 OVERALL EMISSIONS AT GLACIER NATIONAL PARK

GHG emissions for Glacier were estimated using methodologies consistent with those outlined in the *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 1997), EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001* (2003b), and EPA's *Emission Inventory Improvement Program Guidelines, Vol. VIII Estimating Greenhouse Gas Emissions* (2003a). Based on the results of this emissions analysis, Glacier emitted approximately 7,300 metric tons of carbon equivalent (MTCE) in 2002. The sources of these emissions included stationary combustion (i.e., burning of fuel for heating, cooling, and cooking in

buildings and campfires), mobile combustion (i.e., highway and nonroad vehicle use within the park), and landfilled waste (i.e., waste generated in the park but disposed at area landfills). Table 1.3 presents overall emissions by source and by gas for Glacier. Mobile sources comprised the majority of emissions with 84 percent, followed by stationary sources (12 percent), and waste (4 percent) as shown in Figure 1.2. CO_2 accounted for the largest share of emissions (93 percent), which is consistent with national trends. CH_4 and N_2O accounted for 4 and 2 percent of emissions, respectively (see Figure 1.3).

Figure 1.2: Emissions by Source

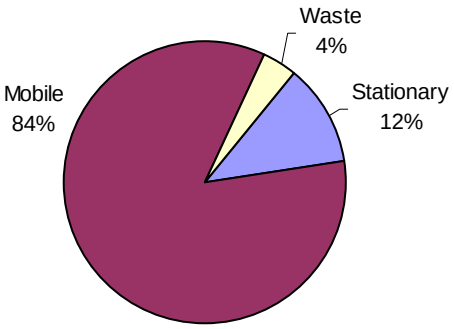


Figure 1.3: Emissions by Gas

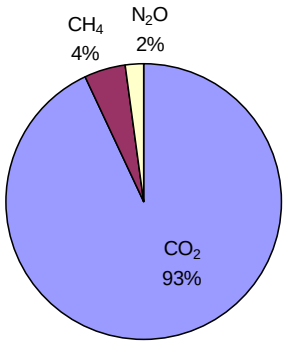


Table 1.3: Overall GHG Emissions

Source / Operation	Emissions (MTCE)			
	CO_2	CH_4	N_2O	Total
Stationary Combustion	**846.0**	**8.1**	**1.7**	**855.9**
Direct Combustion	350.0	8.1	1.7	359.9
Indirect – Purchased Electricity	496.0	NE	NE	496.0
Mobile Combustion	**5,953.8**	**13.4**	**169.1**	**6,136.3**
Highway Vehicles	5,946.2	13.3	168.7	6,128.2
Nonroad Vehicles/Equipment	7.6	0.1	0.4	8.1
Waste	**NA**	**306.4**	**NA**	**306.4**
TOTAL	**6,799.9**	**327.8**	**170.8**	**7,298.5**

Note: Totals may not sum due to independent rounding.
NE = Not Estimated. NA = Not Applicable.

This inventory focuses on GHGs emitted to the atmosphere from activities within the park that present opportunities for GHG reduction. For example, Glacier has control over the type and quantity of its fuel, its vehicle fleet and miles traveled, and the quantity of waste landfilled or recycled. In addition to emissions of GHGs from park, concessionaire, and visitor activities, Glacier's forests exchange carbon with the atmosphere. Because the CFP program is focused on helping parks reduce emissions, carbon flux was treated as a separate, but important, component of the Glacier inventory. Box 1.2 provides a discussion of forest carbon flux at Glacier.

Box 1.2: Carbon in Glacier National Park's Forests

The inventory for Glacier National Park has been compiled to assist park personnel in identifying and reducing emissions where possible. A secondary, though important, consideration is the park's ability to sequester carbon. Carbon sequestration is the net removal of atmospheric CO_2 into long-lived carbon reservoirs, including trees and soil organic matter. Sequestration reduces the rate at which CO_2 accumulates in the atmosphere. As plants undergo photosynthesis (i.e., the process in which plants transform light energy into chemical energy), atmospheric CO_2 is incorporated into living tissues, where carbon may reside until it is consumed or the plant dies and decays, a process that can take up to many centuries. Carbon sequestration varies greatly in forested ecosystems, as the rate of sequestration is sensitive to land management, climate variability, and natural processes like fire. Subtle changes in these variables can alter an ecosystem's condition from a steady state (i.e., one that is neither accumulating nor losing carbon on the whole), to a net source (i.e., an ecosystem that emits more carbon than it stores), or a net sink (i.e., an ecosystem that stores more carbon than it emits). Although these changes often only represent a small proportion of total carbon storage, particularly in heavily-forested Glacier National Park, their magnitude may be important when considering the park's net GHG emissions, as even small changes to such a large carbon reservoir can produce fluxes exceeding those from other GHG sources.

To estimate the carbon stored in Glacier's forests and its average annual change, or flux, U.S. Forest Service measurements (Birdsey and Lewis 2002) of carbon storage and flux by tree-type for the state of Montana since 1997 were combined with park-level area data for each forest type. EPA estimates of carbon distribution within these ecosystems (2003) were then applied to apportion carbon to various pools (i.e., trees, soils, forest floor, understory, or dead wood). This method indicates that, on average, Glacier National Park sequestered 79 thousand metric tons of carbon equivalent (MTCE) in 2002, making Glacier a net sink. This flux rate represents 0.17 percent of an estimated 46 million MTCE found in the park's forests. Soils were the largest carbon reservoir (42 percent), followed by trees (39 percent).

A great deal of uncertainty is inherent in these estimates. They could be refined with measurements of carbon stocks and a current tally of acreage by land cover type in Glacier National Park. They might also be improved by formally reconciling model simulation results of carbon stocks, such as Keane et al.'s (1997), with measured quantities. Keane et al. have simulated carbon fluxes and stock estimates for certain forest pools in the McDonald and St. Mary drainages of Glacier National Park. Scaling these simulated estimates to the park as a whole and comparing them to actual measurements would greatly improve the carbon sequestration estimates presented here. Unfortunately, these improvements were not feasible within the time and resource constraints of this project.

1.7 REPORT STRUCTURE

Inventory estimates for Glacier are organized by the source category and then by the specific activities generating emissions. The structure deviates from typical GHG inventories, which report CO_2 emissions for stationary and mobile combustion separately from CH_4 and N_2O emissions. The reason for this change is to make it easier for park employees to identify and absorb information pertaining to their areas of expertise (e.g., facility management). Each chapter provides an overview of the source category, results, and a brief discussion of the methodology and data sources used to estimate emissions. Appendices A through C provide more detailed information on activity data and emission factors used in the calculations.

The remainder of this report is structured as follows:

- Chapter 2: Stationary Combustion
- Chapter 3: Mobile Combustion
- Chapter 4: Waste
- Chapter 5: References
- Appendix A: Stationary Combustion Background Tables
- Appendix B: Mobile Combustion Background Tables
- Appendix C: Waste Disposal Background Tables

2 STATIONARY COMBUSTION

Greenhouse gases (GHGs) are emitted as fuels are burned for energy in both stationary and mobile sources. At Glacier, stationary emissions result from the burning of natural gas, distillate fuel, and propane in park boilers and generators, wood in woodstoves and campfires, as well as the burning of various fuels at electric power facilities to produce electricity that is consumed in the park. Stationary emissions associated with combustion occurring within park boundaries result from activities such as heating of buildings, cooking, and campfires. Because the peak season for visitors occurs between May and October, fuel use at lodges, campsites, and other park and concessionaire operations within the park is at its highest during these months of the year. Emissions that occur as a result of park activities but occur outside of park boundaries, such as at a power generation facility, are referred to as indirect emissions. Indirect GHG emissions can be reduced by decreasing electricity consumption within the park (e.g., implementing energy efficiency programs, improving insulation) and/or by purchasing electricity generated using lower carbon fuels. For example, some electricity providers will offer a higher fraction of hydroelectric or wind power to their customers, thereby reducing the GHG impact of each unit of electricity consumed. Reducing fuel use and electricity consumption also offers monetary benefits for the park (see Box 2.1).

Box 2.1: Reducing GHGs while Saving Money

If both the park and its concessionaires were able to reduce their electricity purchases by 20 percent (about 410 thousand kWh for the park and 1 million kWh for concessionaires, of which Glacier Park, Inc. accounted for 97 percent), roughly 100 metric tons of carbon equivalent would be avoided. This reduction would save the park roughly $25,000 and the concessionaires $63,000 per year (based on the park's 2002 kWh usage and rate of $0.0622/kWh charged by Flathead Electric Cooperative).

For this inventory, we estimated carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from stationary fuel combustion and CO_2 emissions from purchased electricity. We limited our estimates of emissions from purchased electricity to CO_2 for two reasons. First, whereas CO_2 emissions from this source are primarily dependent on the carbon content of the fuel, emissions of CH_4 and N_2O from purchased electricity are much more complex. The characteristics of the fuel, combustion technology, control technology, environmental conditions, and other factors can affect the amount of CH_4 and N_2O emitted. This information was not available at the level of detail necessary to estimate CH_4 and N_2O from indirect combustion. Because a more simplified method using specific factors is available for estimating CH_4 and N_2O from direct combustion, these emissions were calculated. Second, emissions of CH_4 and N_2O from purchased electricity are very small in comparison to CO_2 emissions from this source. Emissions of these gases from both direct and indirect stationary combustion only represent 0.4 percent of U.S. emissions from stationary fuel combustion, while CO_2 represents nearly all emissions from this source (EPA 2003b).

The sections that follow discuss emissions from stationary combustion and provide an overview of the methodology and data sources used in the calculations.

2.1 RESULTS

In 2002, Glacier National Park emitted approximately 860 metric tons of carbon equivalent (MTCE) from stationary combustion sources. This quantity represents 12 percent of overall greenhouse gas emissions from Glacier. Nearly all of these emissions (99 percent) were CO_2, which is consistent with national and most state emission inventories. As explained above, stationary combustion emissions are comprised of emissions from stationary combustion sources within park boundaries (e.g., boilers, furnaces, water heaters) as well as

emissions from purchased electricity. Of Glacier's total emissions from stationary combustion, emissions from purchased electricity were greater than those from direct fuel use activities within park boundaries (500 MTCE versus 360 MTCE).

As Table 2.1 indicates, concessionaire operations accounted for 60 percent (or approximately 510 MTCE) of total GHG emissions from stationary sources. While the park consumed more fuel for direct combustion within the park boundaries, concessionaire operations used roughly 2.5 times more electricity than that purchased for park operations. Higher electricity demand by concessionaires may be attributed to their operation of a large number of lodges. For instance, Glacier Park, Inc. operates seven lodges/hotels within park boundaries and used a total of nearly 5 million kWh of electricity in 2002.

The majority, or 58 percent, of emissions from park-owned operations were from stationary fuel combustion within the park. For standard building and facility operations, the park and concessionaires consumed far more natural gas than petroleum. In fact, natural gas represented over 80 percent of fuels burned in the park. This is significant because natural gas has a lower carbon content and therefore results in lower emissions than petroleum. CH_4 and N_2O emissions from park-owned operations were much higher than they were for concessionaires primarily due to wood burned for campfires. As indicated in Table 2.2, park-owned operations accounted for about 89 percent of petroleum emissions and 92 percent of wood emissions in the park. The park and concessionaires emitted comparable quantities of GHGs from natural gas consumption.

Table 2.1: Summary of CO_2, CH_4, and N_2O Emissions from Stationary Combustion

Source / Operation	Emissions (MTCE)			
	CO_2	CH_4	N_2O	Total
Fuel Combustion in Park	**350.0**	**8.1**	**1.7**	**359.9**
Park-Owned Operations	193.3	7.2	1.5	202.1
Concessionaire-Owned Operations	156.7	0.9	0.2	157.8
Purchased Electricity	**496.0**	**NE**	**NE**	**496.0**
Park-Owned Operations	141.6	NE	NE	141.6
Concessionaire-Owned Operations	354.4	NE	NE	354.4
TOTAL	**846.0**	**8.1**	**1.7**	**855.9**
Park-Owned Operations	**334.9**	**7.2**	**1.5**	**343.6**
Concessionaire-Owned Operations	**511.1**	**0.9**	**0.2**	**512.2**

Note: Totals may not sum due to independent rounding.
NE = Not Estimated.

Table 2.2: Summary of CO_2, CH_4, and N_2O Emissions from Stationary Combustion within Park Boundaries, by Fuel Type

Source / Operation	Emissions (MTCE)			
	CO_2	CH_4	N_2O	Total
Natural Gas	**304.5**	**0.6**	**0.2**	**305.3**
Park-Owned Operations	152.7	0.3	0.1	153.1
Concessionaire-Owned Operations	151.9	0.3	0.1	152.2
Petroleum	**45.5**	**0.1**	**0.1**	**45.8**
Park-Owned Operations	40.7	0.1	0.1	40.9
Concessionaire-Owned Operations	4.9	+	+	4.9
Wood	**NA**	**7.4**	**1.4**	**8.8**
Park-Owned Operations	NA	6.8	1.3	8.1
Concessionaire-Owned Operations	NA	0.6	0.1	0.7
TOTAL	**350.0**	**8.1**	**1.7**	**359.9**
Park-Owned Operations	**193.3**	**7.2**	**1.5**	**202.1**
Concessionaire-Owned Operations	**156.7**	**0.9**	**0.2**	**157.8**

Note: Totals may not sum due to independent rounding.
NA = Not Applicable.
+ Does not exceed 0.05 MTCE.

2.2 METHODOLOGY AND DATA SOURCES

In order to estimate emissions from stationary sources, data on fuel consumption and electricity purchases (from electricity bills) were requested from the park and from key concessionaires. The sources of these data are presented in Table 2.3.

The Intergovernmental Panel on Climate Change (IPCC) provides guidance on the methodologies for estimating GHG emissions from stationary combustion (1997). The methodology used to estimate CO_2 from direct combustion is based on the carbon content of each fuel, while the methodology used to estimate CH_4 and N_2O is based on the use of gas- and sector-specific emission factors.

To estimate CO_2 emissions from direct combustion in the park, data on natural gas and petroleum consumption were converted to energy units (i.e., British thermal units, Btu) and multiplied by fuel-specific carbon contents. The resulting carbon content for each fuel was multiplied by the fraction of carbon assumed to be oxidized to the atmosphere. See Appendix A for Glacier fuel consumption information (Table A-1) and heat contents, carbon contents, and oxidation factors (Table A-2). Note that CO_2 emissions from wood combustion were not measured in an effort to maintain consistency with the IPCC methodology, which does not count CO_2 emissions from sustainable biogenic sources, such as wood (IPCC 1997).

To estimate CH_4 and N_2O emissions from direct stationary combustion, we followed the IPCC Tier 1 approach (IPCC 1997). First, natural gas and petroleum energy data were adjusted from higher to lower heating values.[9] Wood data were converted to energy units by multiplying by the typical net calorific value (IPCC 1997). Once fossil fuel and wood consumption data were in the proper units, they were multiplied by IPCC fuel-specific emission factors (provided in Table A-2).

[9] Fuel use in the United States is typically measured in higher heating or gross calorific values (GCV). Since the emission factors are based on fuel reported in lower heating or net calorific values (NCV), energy content in GCV was converted to NCV.

The methodology employed for estimating indirect CO_2 emissions from electricity is described in the World Resources Institute and the World Business Council for Sustainable Development's *GHG Protocol Initiative* (2001), as well as EPA's Climate Protection Partnerships Division's *Climate Leaders Greenhouse Gas Inventory Protocol* (2002). First, the quantity of electricity purchased by the park and concessionaires (provided in Table A-3) was adjusted upward to reflect the amount of electricity that was originally generated to meet the electricity consumed by the park. This step is necessary because approximately 9 percent of electricity is assumed to be lost in transmission and distribution (EIA 2003). The resulting net electricity generated was multiplied by a CO_2 emission factor from EPA's eGRID model (2003a).[10] This owner-based factor (provided in Table A-4) represents the average CO_2 emission rate for electricity in the Bonneville Power Administrator power control area (PCA), in which Glacier National Park is located (EPA 2003a). The specific equations used in these calculations can be found in *Gateway National Recreation Area's Criteria Air Pollutant and Greenhouse Gas Emissions Inventory* (ICF 2003).

Table 2.3: Data Sources for Estimation of GHG Emissions from Stationary Combustion

Source	Data Source
Activity Data	
Glacier Park fuel use and electricity purchased data	Summerfield 2003
Concessionaire fuel use and electricity purchased data	Meredith 2003
Glacier Park Inc.	Baker 2003
Glacier Park Boat Co.	Burch 2003
Montana House	Jungster 2003
Cedar Tree and Apgar Village Lodge	Lundgren 2003
Sperry Chalet	Luding 2003
Glacier Wilderness Guides	Coughlin 2003
Factors	
Heat contents, carbon contents, fraction oxidized, and heating value conversions	EPA 2003b
CH_4 and N_2O emission factors and net calorific value for wood	IPCC 1997
Power control area emission factor	EPA 2003a
Electricity loss factor	EIA 2003

[10] http://www.epa.gov/cleanenergy/egrid/index.html

3 MOBILE COMBUSTION

Mobile sources emit carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from the combustion of fossil fuels. In 2002, the transportation sector was the single greatest emitter of greenhouse gases (GHGs) in Glacier, accounting for 84 percent of the park's total emissions. Glacier's mobile emission sources consisted primarily of highway vehicles driven within park boundaries by park and concessionaire personnel and by visitors. Nonroad mobile sources such as boats, tractors, lawn mowers, and other equipment also contributed to Glacier's GHG emissions, but to a much smaller extent.

The two most important factors driving highway emissions are the number of vehicles and the miles traveled by each vehicle within park boundaries. Although park employees and concessionaires travel more miles within the park during the course of a year than most visitors would ever drive, the high number of visitor vehicles in Glacier and the relatively high number of miles driven by each visitor caused visitor vehicle emissions to account for the largest share of GHG emissions (93 percent). Therefore, taking steps to reduce visitor vehicle miles traveled within the park presents the greatest potential for emission reductions. Glacier currently offers a hiker/visitor shuttle; however, it runs infrequently and has not significantly impacted visitor vehicle use in the park. Glacier plans to institute a more substantial, convenient, attractive, and frequent visitor/hiker shuttle system (see Box 3.1).

Box 3.1: Saving GHGs while Transporting Visitors

Parking problems, noise, traffic, air pollution – all of these driving impacts will be improved by the establishment of a visitor shuttle system for the Going-to-the-Sun Road. Not only will the shuttle alleviate these impacts—if the number of visitors stays about the same—but it will also significantly reduce the park's GHG emissions.

If the park were able to reduce the current level of visitor driving by 20 percent, over 1,140 metric tons of carbon equivalent, or 19 percent of the park's 2002 mobile emissions would be avoided.

Despite the large share of emissions from visitor vehicles, park and concessionaire vehicle use also offers opportunities for reducing emissions. Unlike visitor vehicle emissions, the park has some control over *what type* of vehicles are driven in addition to *how much* they are driven. By promoting alternative fuel use and reducing miles traveled by employees, the park and its concessionaires will reduce the amount of GHGs emitted to the atmosphere. In addition, they will demonstrate the park's commitment to reducing GHGs to

Box 3.2: Setting an Example

The park and its concessionaires are already pursuing a reduction of their GHG emissions through the initiatives outlined below. In addition to reducing the park's GHG emissions, these efforts provide visitors with an example of good environmental stewardship and demonstrate how effective GHG reductions can be achieved affordably and without disrupting day-to-day park operations and business practices.

Red Propane Buses. Glacier Park, Inc., the largest concessionaire at Glacier, is pursuing the use of alternative fuels through its use of red buses retrofitted to run on propane. These buses reduce GHGs by (1) using a less carbon-intensive fuel that produces fewer GHGs per gallon than traditional fuels, and (2) avoiding the energy costs of building new buses.

Biodiesel Fuel Use. In 2003, the park began using E10 (10 percent ethanol) to displace gasoline and B20 Biodiesel (20 percent soybean oil) in place of diesel. The use of these alternative fuels saved 34 MTCE, or about 1 percent of the park's CO_2 emissions the previous year. This action is roughly equivalent to removing 24 passenger cars from the road each year.

Reducing Employee Driving. Glacier is currently investigating ways to reduce employee driving on the job. To reduce frequent short distance trips, the park plans on purchasing red bikes for its employees to use for commuting between neighboring buildings. The park is also considering ways to encourage employees to carpool to and from work. If in-park employee driving decreased by 20 percent, 49 MTCE would be avoided.

visitors (see Box 3.2).

The sections that follow discuss the results of our analysis of emissions from mobile combustion and an overview of the methodology and data sources used in the calculations.

3.1 RESULTS

In 2002, Glacier National Park emitted approximately 6,100 metric tons of carbon equivalent (MTCE) from mobile sources. This quantity represents 84 percent of overall GHG emissions from Glacier. Nearly all of these emissions (97 percent) were CO_2, analogous to the proportion seen in most national and state inventories. Emissions of CH_4 and N_2O accounted for 0.2 and 3 percent, respectively, of total emissions. For mobile sources, CO_2 emissions from mobile combustion are driven by fuel use, while CH_4 and N_2O emissions are determined based on vehicle miles traveled (VMT) and vehicle type.

As shown in Table 3.1, visitor activities were responsible for 93 percent of total GHG emissions from mobile sources (or about 5,700 MTCE). The high contribution of GHGs from visitors is largely due to the number of VMT by visitors in the park. Although the average number of miles traveled by park and concessionaire vehicles was higher than the average miles traveled by visitor vehicles, visitor VMT represented 95 percent of all miles driven in the park. This is because the VMT differences were more than made up for by the high number of visitor vehicles (550 thousand) as compared to park and concessionaire vehicles (about 300 in use in 2002). Collectively, park, concessionaire, and visitor vehicles traveled over 41 million miles in the park in 2002. Table B-4 in Appendix B presents VMT estimates by fuel and vehicle type due to park, concessionaire, and visitor activities.

Park and concessionaire mobile sources contributed to a much smaller portion of Glacier's total emissions, representing 4 and 3 percent, respectively. Park-leased vehicles were responsible for less than 1 percent of Glacier's emissions. These percentages are consistent with the smaller park and concessionaire employee populations and miles traveled compared to that of visitors.

Nonroad sources comprised less than 1 percent of Glacier's mobile emissions. Nonroad sources include vehicles and equipment such as tractors and lawn mowers, as well as motorized boats. Due to data limitations, emissions from nonroad vehicles and equipment were estimated only for park operations; emissions from boats were estimated for boats owned and operated by the park and by Glacier Park Boat Company.

Table 3.1: Summary of CO_2, CH_4, and N_2O Emissions from Mobile Combustion

Source / Operation	Emissions (MTCE)			
	CO_2	CH_4	N_2O	Total
Highway Vehicles	**5,946.2**	**13.3**	**168.7**	**6,128.2**
Park-Owned Vehicles	210.4	0.4	5.4	**216.2**
Park-Leased Vehicles	26.4	0.1	0.6	**27.0**
Concessionaire-Owned Vehicles	163.9	0.4	3.3	**167.6**
Visitor Vehicles	5,545.6	12.4	159.4	**5,717.3**
Nonroad Sources	**7.6**	**0.1**	**0.4**	**8.1**
Equipment/Nonroad Vehicles	NAV	0.1	0.3	**0.4**
Park-Owned Vehicles	IE	0.1	0.3	**0.4**
Park-Leased Vehicles	NA	NA	NA	**NA**
Concessionaire-Owned Vehicles	NAV	NAV	NAV	**NAV**
Visitor Vehicles	NA	NA	NA	**NA**
Boats	**7.6**	**+**	**0.1**	**7.7**
Park-Owned Vehicles	IE	+	+	**+**
Park-Leased Vehicles	NA	NA	NA	**NA**
Concessionaire-Owned Vehicles[1]	7.6	+	0.1	**7.7**
Visitor Vehicles	NAV	NAV	NAV	**NA**
TOTAL	**5,953.8**	**13.4**	**169.1**	**6,136.3**
Park-Owned/Leased Operations	**236.8**	**0.5**	**6.3**	**243.7**
Concessionaire-Owned Operations	**171.5**	**0.4**	**3.4**	**175.3**
Visitor Operations	**5,545.6**	**12.4**	**159.4**	**5,717.3**

Note: Totals may not sum due to independent rounding.
NE = Not Estimated. IE = Included Elsewhere. NA = Not Applicable. NAV = Not Available.
+ Does not exceed 0.05 MTCE.
[1] Glacier Park Boat Company

3.2 Methodology and Data Sources

3.2.1 Highway Vehicles

In order to estimate emissions from mobile highway sources, information on vehicle fuel use, VMT, and vehicle vintage, make, and model was requested from the park and from key concessionaires. The sources of these data are presented in Table 3.2.

The Intergovernmental Panel on Climate Change (IPCC) provides guidance on the methodologies for estimating GHG emissions from mobile combustion (1997). The methodology used to estimate CO_2 is based on fuel consumption, since the amount of CO_2 is primarily dependent on the carbon content of gasoline. Park and concessionaire motor gasoline, diesel, and propane fuel consumption data for vehicles (presented in Table B-1) were first converted to energy units (i.e., British thermal units, Btu) and multiplied by fuel-specific carbon coefficients. The resulting total carbon content for each fuel was then multiplied by the fraction of carbon assumed to be oxidized to the atmosphere (99 percent). In order to estimate emissions from visitor vehicles and from concessionaires that did not provide fuel consumption information for their vehicles (e.g., Sperry Chalet), we estimated fuel consumption by dividing VMT estimates (discussed below) by U.S. average fuel economy in units of miles per gallon (FHWA 2002). This was done for each vehicle type and age class. See Table B-2 for heat contents, carbon contents, oxidation factors, and Table B-3 for average fuel economy.

Unlike CO_2, emissions of CH_4 and N_2O are dependent on vehicle type and emission control technology. The methodology used to estimate these emissions is similar to the methodology described in *Gateway National Recreation Area's Criteria Air Pollutant and Greenhouse Gas Emissions Inventory* (ICF 2003). As in the Gateway Inventory, some data gaps were filled using national average data taken from EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001* (2003). The method used to estimate emissions from this source is consistent with international estimation guidelines, as set forth in IPCC's *Revised 1996 Guidelines for National Greenhouse Gas Inventories* (1997). An explanation of the differences between the Gateway approach and the method implemented for Glacier is provided below:

Age Distribution of Park and Concessionaire Fleets: Data were available on the model years of park vehicles (both owned and leased) and concessionaire vehicles; therefore, park and concessionaire data, not national data, on the age distribution of the vehicle fleets were used.

Visitor VMT: The number of visitor vehicles per month was estimated by dividing the monthly visitor populations by the average vehicle occupancy, both obtained from the *Glacier National Park Traffic and Parking Statistics Report* (Law 2003). The average VMT for each visitor car was estimated by Summerfield (2003). He estimated that each vehicle travels an average of 75 miles during the five months that all park roads are open, and 25 miles during the remaining seven months. The number of visitor vehicles entering the park each month was then multiplied by the average VMT for that month. Estimates on the type (Glacier 2002) and age of vehicles driven by park visitors (CE-CERT 2003, provided in Table B-7) were then used to allocate total visitor VMT to each emission control technology.

Concessionaire VMT: Glacier Park, Inc. provided VMT data for a six-month time period, during which the majority, approximately 97.5 percent, of driving occurred (according to Potter 2004). Because information was not available on vehicle and fuel types, vehicle types were assigned based on the vehicle descriptions. Additionally, all vehicles were assumed to use gasoline except for the buses retrofitted to run on propane, and vehicles specifically denoted as diesel. VMT for Glacier Wilderness Guides was calculated based on reported fuel consumption and assuming an average fuel economy of 19 mpg (the fuel economy of Cedar Tree and Apgar Village). Based on discussions with concessionaire personnel, VMT for Cedar Tree and Apgar Village was calculated assuming 13 vehicles were driven 4.4 miles each for 128 days. Finally, VMT for Montana House was estimated based on the assumption that half the fleet drove 5 miles each day for 180 days.

3.2.2 Nonroad Sources

Data on nonroad fuel consumption were obtained from the same personnel as were data on highway sources. The information was sufficient to estimate emissions from park-owned nonroad vehicles/equipment and boats, as well as emissions from boats owned by Glacier Park Boat Company. Nonroad emissions from other concessionaires were not estimated and are likely to be very small.

The methodology described above for highway vehicles was used to estimate CO_2 emissions from nonroad sources. The methodology for estimating CH_4 and N_2O emissions is similar to that described in ICF (2003), which employs the methods and some default data used to estimate national emissions for EPA (2003) and is consistent with international guidelines, set forth in IPCC (1997). The methodology differs only in the way fuel consumption was calculated.

Data on fuel consumed by park-owned nonroad sources were not provided by Glacier staff. Instead, consumption was calculated by subtracting the estimated gasoline and diesel consumed by park-owned

highway vehicles from the park's total consumption of these fuels. This methodology was also used to calculate nonroad vehicle/equipment fuel consumption by Glacier Park, Inc. However, the resulting estimate provided a negative number for nonroad fuel consumption, so nonroad emissions from Glacier Park, Inc. were not included in estimates of nonroad emissions.

Please refer to Tables B-5 and B-6 for the emission factors used to calculate CH_4 and N_2O emissions for all mobile sources.

Table 3.2: Data Sources for Estimation of GHG Emissions from Mobile Combustion

Source	Data Source
Activity Data	
Glacier Park transportation fuel use, vehicle type data, and miles traveled data; visitor vehicle miles traveled estimates	Summerfield 2003
Concessionaire transportation fuel use, vehicle type, and miles traveled data	Meredith 2003
Glacier Park Inc.	Baker 2003, Potter 2004
Glacier Park Boat Co.	Burch 2003
Montana House	Jungster 2003
Cedar Tree and Apgar Village Lodge	Lundgren 2003
Sperry Chalet	Luding 2003
Glacier Wilderness Guides	Coughlin 2003
Number of visitor vehicles	Law 2003
Vehicle age distribution used for park visitor vehicles	CE-CERT 2003
Vehicle type of visitor vehicles	Glacier 2002
Factors	
Heat contents, carbon contents, and fraction oxidized factors	EPA 2003
CH_4 and N_2O emission factors for highway vehicles	EPA 2004
CH_4 and N_2O emission factors for nonroad vehicles	IPCC 1997
Density values for diesel and gasoline	EPA 2004
U.S. average fuel economy	FHWA 2002

4 WASTE DISPOSAL

The greatest source of greenhouse gas (GHG) emissions resulting from municipal solid waste (MSW) disposal is landfill methane (CH_4). CH_4 is emitted as organic materials (i.e., materials containing carbon) decompose in an oxygen-deprived (anaerobic) environment. Estimates of landfill CH_4 emissions for Glacier are based on the amount of MSW that was disposed in garbage receptacles within park boundaries and subsequently sent to a landfill. The waste in these receptacles was generated by a combination of park employees, concessionaires, and visitors; however, the waste disposal was handled by the park and the concessionaires. As a result, emissions from solid waste disposal at Glacier were attributed to the park or to specific concessionaires, based on the tonnages they reported.

Although emissions from the landfilling of MSW generated at the park actually occur at the landfill site, and therefore take place outside of park boundaries, they are included in Glacier's GHG inventory because the waste-generating activities underway *within* the park are indirectly responsible for these emissions. Should the park or the concessionaires choose to implement or expand waste reduction efforts, these emissions could be reduced. The park and its concessionaires already recycle some materials, including glass, cardboard, aluminum, and paper. In 2002, the recycling of cardboard, plastic, and paper by the park reduced CH_4 emissions by about 5.6 metric tons of carbon equivalent (MTCE), which is roughly equivalent to removing four cars from the road each year. These efforts also saved 99 million British thermal units (Btu) of energy, which equates to about 17 barrels of oil or 800 gallons of gasoline.[11] Expanding on these recycling efforts even further and reducing waste in other ways could significantly lower Glacier's waste-related GHG emissions (see Box 4.1).

The sections that follow discuss the results of our analysis of emissions from MSW disposal and an overview of the methodology and data sources used in the calculations.

Box 4.1: Reducing GHGs by Reducing Waste

Glacier can reduce its GHG emissions and save energy simply by sending less waste to landfills. By increasing the recovery of recyclable materials, Glacier can reduce emissions from landfills and reduce emissions that occur "upstream" as virgin raw materials are displaced by recycled inputs. Glacier can further reduce waste generation and emissions by consuming less material in the first place. One option might be to evaluate purchasing policies and to attempt to purchase items in bulk to reduce the overall need for packaging materials. Personnel can also reuse items, e.g., using cardboard boxes from received shipments as storage containers.

If Glacier's 2002 wastes were reduced by one third, its emissions for that year would have been about 40 MTCE lower. Since waste produces CH_4 emissions over a 30-year period, reducing waste disposal now will have an even greater impact in the long run.

4.1 RESULTS

The emissions attributed to the waste sector for Glacier are solely from the CH_4 generated by the anaerobic decomposition of organic wastes in landfills.[12] In 2002, Glacier National Park emitted approximately 300 MTCE from MSW disposal. This quantity represents the largest share of CH_4 emissions in the park (93 percent), and 4 percent of the park's overall GHG emissions.

As shown in Table 4.1, the majority of Glacier's waste emissions are attributed to concessionaires, comprising 62 percent (190 MTCE) of the park's emissions from this source. The remaining emissions

[11] Emission reductions, energy savings, and equivalencies estimated using recycling tonnage data from the Park (Summerfield 2003) and EPA's WAste Reduction Model (WARM), available online at http://yosemite.epa.gov/oar/globalwarming.nsf/WARM. Note that these reductions reflect emissions reduced throughout the material life-cycle and are therefore not directly comparable to emissions from waste sector activities alone.

[12] There are other GHG emissions associated with MSW disposal, including carbon dioxide and nitrous oxide emissions from

(roughly 120 MTCE) are due to waste managed by the park. Possible explanations for why concessionaries generated more waste than the park include the larger number of concessionaire employees (six times greater than the average year-round number of park employees), concessionaire activities being more waste-intensive than park activities (e.g., food wastes, packaging associated with gift store items), and/or a greater share of visitor-generated waste being disposed in concessionaire receptacles. Landfill emissions associated with waste disposal by various concessionaires are presented in Table 4.2.

Table 4.1: Summary of GHG Emissions from MSW Disposal

Source	CH_4 Emissions (MTCE)
Waste Disposed by Park	115.9
Waste Disposed by Concessionaires	190.5
TOTAL	**306.4**

Table 4.2: Summary of GHG Emissions from MSW Disposal by Concessionaire

Concessionaire	CH_4 Emissions (MTCE)
Glacier Park Inc.	164.5
Montana House	1.1
Sperry Chalet	1.1
Cedar Tree & Apgar Village Lodge	22.9
Glacier Wilderness Guides	0.6
Glacier Park Boat Co.	0.2
TOTAL	**190.5**

Note: Totals may not sum due to independent rounding.

4.2 METHODOLOGY AND DATA SOURCES

In order to estimate emissions from MSW disposal, the park and its concessionaires were asked to provide the mass of MSW disposed annually and the name of the landfill where the waste is ultimately disposed (see Table C-1 in Appendix C). The sources of these data are presented in Table 4.3. Instead of providing information on the mass of MSW disposed, two concessionaires–Montana House and Sperry Chalet–were only able to provide information on the volume disposed (in cubic yards for Montana House, and in dump loads per week for Sperry Chalet). The weights of these MSW volumes were estimated by assuming: (a) a MSW density of 0.05 short tons per cubic yard of uncompacted waste (EPA 1998) and (b) a typical dump load capacity of 2.2 short tons per load, respectively.

Emissions from MSW were based on estimates of waste disposal. The methodology used is similar to that described in *Gateway National Recreation Area's Criteria Air Pollutant and Greenhouse Gas Emissions Inventory* (ICF 2003) and is consistent with EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001* (2003a) and international estimation guidelines, as set forth in IPCC's *Revised 1996 Guidelines for National Greenhouse Gas Inventories* (1997). An explanation of the differences between the Gateway approach and the method implemented for Glacier is provided below:

Park Population: Two data sources were used to obtain the thirty-year historical visitor population for Glacier (NPS 2003 and Law 2003). Park and concessionaire employee population data were added to the

incineration. Since all of Glacier's waste is landfilled, there was no need to estimate any other disposal-related emissions.

visitation population. The sum of these three populations was used to back calculate the estimates of per capita landfilling tonnages.

Destination Landfills: All waste was assumed to go to either Flathead County Landfill or Northern Montana Joint Refuse Disposal District Landfill, based on data received from the park and concessionaire contacts. For concessionaires that did not provide information on a destination landfill, landfills were assigned based upon proximity. Since CH_4 emissions are based on the amount of waste disposed over a 30-year period, waste was assigned to one of the two landfills named above. Because the Northern Montana Joint Refuse Disposal District began accepting MSW in 1992, waste generated from 1972-1991 was assumed to have been disposed in Flathead County Landfill. Flathead County Landfill is considered a large, arid landfill, while Northern Montana Joint Refuse Disposal District is considered to be a small, arid landfill (EPA 2003b). These designations correspond to the regression equations used to calculate landfill CH_4 generation as provided in EPA (1999). Information on the amount of CH_4 captured by flaring projects at Flathead County Landfill was obtained from Forest (2003).[13] Northern Montana Joint Refuse Disposal District (NMJRDD) does not have a CH_4 recovery system in place. Waste-in-place, CH_4 recovery, CH_4 generation and other characteristics for Flathead County Landfill and NMJRDD are provided in Table C-2. Table C-3 presents the equations used to estimate CH_4 generation.

Table 4.3: Data Sources for Estimation of CH_4 Emissions from Landfilled Waste

Source	Data Source
Activity Data	
Glacier Park waste disposal data	Summerfield 2003
Concessionaire waste disposal data	Meredith 2003
Glacier Park Inc.	Baker 2003
Glacier Park Boat Co.	Burch 2003
Montana House	Jungster 2003
Cedar Tree and Apgar Village Lodge	Lundgren, 2003
Sperry Chalet	Luding 2003
Glacier Wilderness Guides	Coughlin 2003
Number of park employees	Fitzpatrick 2003
Number of concessionaire employees	Baker 2003; Meredith 2003
Number of visitors for 1972-1989	NPS 2003
Number of visitors for 1990-2002	Law 2003
CH_4 flared at Flathead County Landfill	Forest 2003
Destination landfill characteristics	EPA 2003b
Factors	
MSW density	EPA 1998
CH_4 generation equations	EPA 1999

[13] CH_4 recovery at Flathead County Landfill included flares only (i.e., no landfill-gas-to-energy projects are in place).

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APPENDIX A: STATIONARY COMBUSTION BACKGROUND TABLES

This appendix provides further background information on the activity data and factors used in the estimation of greenhouse gas emissions from stationary combustion at Glacier.

Table A-1: Stationary Fuel Consumption for Park and Concessionaire Operations in 2002

Park Operation/Source	Fuel Consumption (energy units)
Natural Gas	**(MMBtu)**
Park-Owned Operations	10,604
Concessionaire-Owned Operations	10,547
Petroleum	**(MMBtu)**
Park-Owned Operations	2,248
Concessionaire-Owned Operations	284
Wood	**(MJ)**
Park-Owned Operations	3,953,058
Concessionaire-Owned Operations	329,421

Source: Summerfield 2003; Baker 2003; Meredith 2003; Burch 2003; Jungster 2003; Lundgren 2003; Luding 2003; Coughlin 2003.

Table A-2: Stationary Combustion Conversions and Emission Factors

Fuel Type	Heat Content	Carbon Content Coefficient (Tg C/QBtu)	Fraction Oxidized	Heating Value Conversion	Emission Factors (g gas/GJ)	
					CH_4	N_2O
Natural Gas	**(Btu/ft^3)**					
Natural Gas	1,027	14.47	99.5%	90%	5.0	0.1
Petroleum	**(MMBtu/barrel)**					
Distillate Fuel Oil	5.825	19.95	99.0%	95%	10.0	0.6
Propane	3.836	17.20	99.5%	95%	10.0	0.6
Wood	**(MJ/kg)**					
Wood	16.6[a]	NA	NA	NA	300.0	4.0

Sources: Heat contents, carbon contents, fraction oxidized factors, and heating value conversions from EPA 2003b. Emission Factors and net calorific value for wood from IPCC 1997.
[a] Represents typical net calorific value for wood with 15 percent moisture.

Table A-3: Electricity Purchased by Glacier Park and Concessionaires in 2002

Source/Park Operation	Purchased Electricity (kWh)
Park-Owned	2,035,500
Concessionaire-Owned	5,096,796
TOTAL	**7,132,296**

Source: Summerfield 2003; Baker 2003; Burch 2003; Jungster 2003; Lundgren 2003.

Table A-4: Electricity Emission Factors

Power Control Area	PCA Emission Factor (lbs CO_2/MWh) [a]	Electricity Loss Factor [b]
Bonneville Power Administrator [c]	511.55	9%

Source: Emission factor from EPA 2003a. Electricity loss factor from EIA 2003.

[a] Emission factor selected for the PCA.

[b] Calculations account for an average electricity loss factor of 9 percent based on the average U.S. portion lost during transmission and distribution.

[c] Bonneville Power Administrator PCA fuel mix consists of approximately 51% hydro, 20% coal, 18% nuclear, 9% gas, 2% biomass, and <1% oil.

APPENDIX B: MOBILE COMBUSTION BACKGROUND TABLES

This appendix provides further background information on the activity data and factors used in the estimation of greenhouse gas emissions from mobile combustion at Glacier.

Table B-1: Mobile Fuel Consumption for Glacier Park and Concessionaire Operations, and Visitor Vehicles in 2002

Park Operation/Source	Fuel Consumption (gallons)	Fuel Consumption (MMBtu)
Mobile		
Petroleum		
Distillate Fuel Oil		
Park-Owned Operations	33,200	4,605
Concessionaire-Owned Operations	3,582	497
Visitors[a]	208,247	28,882
Motor Gasoline		
Park-Owned and Leased Operations	60,900	7,617
Concessionaire-Owned Operations	49,725	6,219
Visitors[a]	2,077,565	259,844
Propane		
Concessionaire-Owned Operations	27,251	2,489

Source: Summerfield 2003; Baker 2003; Meredith 2003; Burch 2003; Jungster 2003; Lundgren 2003; Luding 2003; Coughlin 2003.
[a]Estimated using VMT and miles per gallon.

Table B-2: Mobile Combustion Conversions and Emission Factors for Estimating CO_2

Fuel Type	Heat Content (MMBtu/barrel)	Carbon Content Coefficient (Tg C/QBtu)	Fraction Oxidized
Petroleum			
Distillate Fuel Oil	5.825	19.95	99.0%
Motor Gasoline	5.253	19.34	99.0%
Propane	3.836	17.20	99.5%

Source: EPA 2003.

Table B-3: U.S. Miles Per Gallon

	LDGV, LDDV	LDGT, LDDT	HDGV, HDDV [a]
MPG	22.10	17.60	5.89

Source: FHWA 2002.
Note: These categories include: LDGV: light-duty gas vehicles; LDDV: light-duty diesel vehicles; LDGT: light-duty gas truck; LDDT: light-duty diesel truck; HDGV: heavy-duty gas vehicle; HDDV: heavy-duty diesel vehicle (HDDV).
[a] Derived using weighted average of FHWA Other Single-unit Trucks and Combination Trucks.

Table B-4: Vehicle Miles Traveled in Glacier National Park, 2002

Source Category	Light-Duty Gasoline Vehicles (LDGV)	Light-Duty Gasoline Trucks (LDGT)	Heavy-Duty Gasoline Vehicles (HDGV)	Light-Duty Diesel Trucks (LDDT)	Heavy-Duty Diesel Vehicles (HDDV)	MC	LPG Buses	TOTAL
Park-Owned Vehicles	126,240	719,333	18,716	1,281	101,667			967,237
Park-Leased Vehicles		193,140						193,140
Concessionaire-Owned Vehicles	106,857	539,317	4,344	9,914	19,915		260,698	941,045
Glacier Park Inc.	*99,376*	*466,819*	*4,344*	*9,914*	*18,762*		*260,698*	*859,913*
Montana House	*1,800*	*900*						*2,700*
Sperry Chalet	*800*	*350*						*1,150*
Cedar Tree and Apgar Village	*4,881*	*2,441*						*7,322*
Glacier Wilderness Guides		*66,500*						*66,500*
Glacier Park Boat Company		*2,307*			*1,153*			*3,460*
Visitor Vehicles	19,561,311	16,170,684	1,564,905		1,434,496	391,226		39,122,622
Glacier Park Total	**19,794,408**	**17,622,474**	**1,587,965**	**11,195**	**1,556,078**	**391,226**	**260,698**	**41,224,044**

Note: VMT data for Glacier Wilderness Guides was estimated based on fuel consumption data. All other VMT data were provided by Glacier personnel.

Table B-5: N_2O and CH_4 Emission Factors for Highway Vehicles

Vehicle Type/Control Technology	Emission Factors (g/mi)	
	N_2O	CH_4
Gasoline Passenger Cars		
Low Emission Vehicles	0.0283	0.0402
EPA Tier 1[a]	0.0463	0.0483
EPA Tier 0[a]	0.0816	0.0644
Oxidation Catalyst	0.0518	0.1127
Non-Catalyst Control	0.0166	0.1931
Uncontrolled	0.0166	0.2173
Gasoline Light-Duty Trucks		
Low Emission Vehicles	0.0355	0.0483
EPA Tier 1[a]	0.0580	0.0563
EPA Tier 0[a]	0.1022	0.1127
Oxidation Catalyst	0.0649	0.1448
Non-Catalyst Control	0.0208	0.2253
Uncontrolled	0.0208	0.2173
Gasoline Heavy-Duty Vehicles		
Low Emission Vehicles	0.1133	0.0708
EPA Tier 1[a]	0.1394	0.0966
EPA Tier 0[a]	0.2361	0.1207
Oxidation Catalyst[b]	0.1499	0.1448
Non-Catalyst Control	0.0480	0.2012
Uncontrolled	0.0480	0.4345
Diesel Passenger Cars		
Advanced	0.0161	0.0161
Moderate	0.0161	0.0161
Uncontrolled	0.0161	0.0161
Diesel Light-Duty Trucks		
Advanced	0.0322	0.0161
Moderate	0.0322	0.0161
Uncontrolled	0.0322	0.0161
Diesel Heavy-Duty Vehicles		
Advanced	0.0483	0.0644
Moderate	0.0483	0.0805
Uncontrolled	0.0483	0.0966
Motorcycles		
Non-Catalyst Control	0.0073	0.2092
Uncontrolled	0.0073	0.4184
LPG Buses	0.1502	0.1078

Source: EPA 2004.

Table B-6: N_2O and CH_4 Emission Factors for Nonroad Vehicles

Vehicle Type	Density (kg/gal)		Emission Factors (g/kg fuel)			
			N_2O		CH_4	
	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline
Boats	3.1920	2.8009	0.2300	0.2300	0.0800	0.0800
Other Non-Highway	3.1920	2.8009	0.1800	0.1800	0.0800	0.1800

Source: Density values from EPA (2004). Emission factors from IPCC (1997).

Table B-7: National Parks Study Vehicle Age Distribution used for Visitor Vehicles

Vehicle Model Year	LDV	LDT1	LDT2	LDT3	LDT4	HDV2b	HDV3	HDV4	HDV5	HDV6	HDV7	HDV8a	HDV8b	HDBS	HDBT	MC
2001	15.8%	16.1%	16.1%	0.0%	0.0%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	14.7%	10.0%
2000	15.8%	16.1%	16.1%	22.8%	22.8%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	14.7%	10.0%
1999	15.8%	16.1%	16.1%	22.8%	22.8%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	14.7%	10.0%
1998	15.8%	16.1%	16.1%	22.8%	22.8%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	16.63%	14.7%	10.0%
1997	5.9%	4.3%	4.3%	4.9%	4.9%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	8.8%	10.0%
1996	5.9%	4.3%	4.3%	4.9%	4.9%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	8.8%	10.0%
1995	5.9%	4.3%	4.3%	4.9%	4.9%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	8.8%	10.0%
1994	5.9%	4.3%	4.3%	4.9%	4.9%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	6.77%	8.8%	10.0%
1993	2.5%	2.5%	2.5%	2.6%	2.6%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.0%	5.0%
1992	2.5%	2.5%	2.5%	2.6%	2.6%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.0%	5.0%
1991	2.5%	2.5%	2.5%	2.6%	2.6%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.11%	2.0%	5.0%
1990	1.0%	1.8%	1.8%	1.1%	1.1%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.0%	5.0%
1989	1.0%	1.8%	1.8%	1.1%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1988	1.0%	1.8%	1.8%	1.1%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1987	0.4%	1.0%	1.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1986	0.4%	1.0%	1.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1985	0.4%	1.0%	1.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1984	0.4%	1.0%	1.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1983	0.4%	0.4%	0.4%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1982	0.2%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1981	0.2%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1980	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1979	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1978	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1977	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: CE-CERT 2003.

Note: These categories refer to Mobile 6.2 vehicle classes:

LDV: Light-Duty Vehicles (passenger cars); LDT1: Light-Duty Trucks 1 (0-6,000 lbs. Gross Vehicle Weight Rating (GVWR), 0-3,750 lbs. Loaded Vehicle Weight (LVW));

LDT2: Light-Duty Trucks 2 (0-6,000 lbs. GVWR, 3,751-5,750 lbs. LVW); LDT3: Light-Duty Trucks 3 (6,001-8,500 lbs. GVWR, 0-5,750 lbs. Alternative LVW);

LDT4: Light-Duty Trucks 4 (6,001-8,500 lbs. GVWR, 5,751 lbs and greater ALVW); HDV2b: Class 2b Heavy-Duty Vehicles (8,501-10,000 lbs. GVWR);

HDV3: Class 3 Heavy-Duty Vehicles (10,001-14,000 lbs. GVWR); HDV4: Class 4 Heavy-Duty Vehicles (14,001-16,000 lbs. GVWR);

DV5: Class 5 Heavy-Duty Vehicles (16,001-19,500 lbs. GVWR); HDV6: Class 6 Heavy Duty Vehicles (19,501-26,000 lbs. GVWR);

HDV7: Class 7 Heavy Duty Vehicles (26,001-33,000 lbs. GVWR); HDV8a: Class 8a Heavy-Duty Vehicles (33,001-60,000 LBS. GVWR);

HDV8b: Class 8b Heavy-Duty Vehicles (>60,000 lbs. GVWR); HDBS: School Buses; HDBT: Transit and Urban Buses; MC: Motorcycles.

APPENDIX C: WASTE DISPOSAL BACKGROUND TABLES

This appendix provides further background information on the activity data and factors used in the estimation of greenhouse gas emissions from waste disposal for Glacier.

Table C-1: 2002 MSW Disposal Statistics for Park and Concessionaires

Park Operation/Source	Destination Landfill	2002 MSW Disposed (short tons)
Municipal Solid Waste		
Glacier National Park		**243**
East Side	NMJRDD	*70*
West Side	Flathead Co. LF	*173*
Concessionaires		**417**
Glacier Park Inc.		364
East Side	NMJRDD	*244*
West Side	Flathead Co. LF	*120*
Montana House	Flathead Co. LF	2
Sperry Chalet	NMJRDD	3
Cedar Tree & Apgar Village Lodge	Flathead Co. LF	46
Glacier Wilderness Guides	Flathead Co. LF	1
Glacier Park Boat Co.	Flathead Co. LF	1
TOTAL		**660**

Note: NMJRDD = Northern Montana Joint Refuse Disposal District
Source: Summerfield 2003; Baker 2003; Meredith 2003; Burch 2003; Jungster 2003; Lundgren 2003; Luding 2003; Coughlin 2003.

Table C-2: Destination Landfill Characteristics

Landfill	Waste-In-Place (short tons)	Year Landfill Opened	Landfill Gas Captured per Year (standard cubic feet)	Annual Emissions Reduction from Flare	Annual CH_4 Generated[a] (short tons)
Flathead Co. LF	1,000,000	1972	112,000,000	1,185	4,450
NMJRDD[b]	120,000	1992	0	0	249

[a] Does not reflect emissions reductions from flares.
[b] Northern Montana Joint Refuse Disposal District
Sources: EPA 2003b and Forest 2003.

Table C-3: CH_4 Generation Equations

Large, Arid	3,218 tons CH_4 + (0.001232 tons CH_4/ton WIP x tons WIP)
Small, Arid	0.002079 tons CH_4/ton WIP x tons WIP

Note: WIP = Waste-in-Place
Source: EPA 1999.